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Innovative Concept for an Advanced Hadron Facility Based on a 2 GeV H^- Linac

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INNOVATIVE CONCEPT FOR AN
ADVANCED HADRON FACILITY
BASED ON A 2 GeV H^- LINAC

by

H. A. Thiessen

ABSTRACT

This report presents parameters for an innovative new concept for the design of an advanced hadron facility. We propose combining a cold neutron source with a kaon factory. We also discuss the possibility of a shared target for neutron and neutrino experiments. An initial cost estimate is presented.

Discussions of the past few weeks suggest the following ground rules for an advanced hadron facility design:

1. world's best cold-neutron source - deemed to be 1 MW of beam at 12 Hz and a suitable energy on a high-Z target;
2. world's best kaon factory - deemed to be 60 GeV at 50 μ A (25 μ A if stretcher is omitted);
3. shared target for cold neutrons, stopped-pion neutrino source, and pulsed muons.

In addition, we have considered an rf frequency near 400 MHz for the following reasons:

1. rf separated beams;

2. ability to use every micropulse of LAMPF H^- beam (or that of any modern linac); and
3. higher reliability of klystron-based rf.

We have made a first attempt at such a design that is at least sensible. The design concept consists of:

1. Linac - to increase LAMPF energy to 2 GeV at 500 μA ;
2. LANSCE II - 12 Hz, 2-GeV pulse compressor ring; and
3. 50- μA -60-GeV-12-Hz complex consisting of booster and main ring.

The main-ring lattice is identical to the latest LAMPF II main-ring design.

The rf requirements and stability of such a system have been studied with program RAMA - recently obtained from R. Baartman at TRIUMF (outputs given in Tables I and II). The beam appears to be stable in all rings against all coasting beam instabilities, and the coupled-bunch dipole mode, and also has a reasonable Laslett-tune shift. The one exception is the 60-GeV main ring, which will have some trouble with the longitudinal coupled-bunch dipole mode. The same problem occurred with the earlier LAMPF II design. An active damper can cure this instability.

A summary of the proposed machine parameters is given in Table III, where the previous LAMPF II and PSR designs are also shown for comparison purposes.

Since the booster no longer has to handle the high current required for a neutrino source, we have chosen to lower its repetition rate to 12 Hz (same as main ring) and locate it in the main-ring tunnel. By choosing a higher booster energy, it is possible to use the magnets of the booster as a choke for the main ring, and vice versa, thus saving a large amount on the magnet power supply cost.

BOOSTER		MAIN	
Radius (m)	191.0000	Radius (m)	191.0000
Bend Radius (m)	28.4000	Bend Radius (m)	102.0000
Gamma trans.	20.0000	Gamma trans.	6.8000
Harmonic No.	1700.0000	Harmonic No.	1700.0000
Qx	20.2300	Qx	7.4600
Qz	19.2800	Qz	8.4300
Chamber W./2 (m)	0.1000	Chamber W./2 (m)	0.0300
Chamber H./2 (m)	0.0600	Chamber H./2 (m)	0.0200
Wall Z/n (Ohm)	10.0000	Wall Z/n (Ohm)	10.0000
Prep (Hz)	12.0000	Prep (Hz)	12.0000
Vrf (kV)	600.0000	Vrf (kV)	4000.0002
RMS Disp. (m)	4.0000	RMS Disp. (m)	6.0000
Rise Fraction	0.5000	Rise Fraction	0.5000
Tinj (GeV)	2.0000	Tinj (GeV)	17.0000
Final T (GeV)	60.0000	Final T (GeV)	60.0000

GLOBAL PARAMETERS:

Particle Current (uA) 50.00
 SEXN (pi mm-mr) 10.00
 SEXN (-) 10.00
 EL (eV-s) 0.007500

***EL,SEXN,SEXN = 0.007 10.0 10.0

BOOSTER												MAIN											
Prep= 12.Hz, rise=.50, R=191.0m, h=****, Gt= 20.0, indZ/n= 10.0ohm, Rp=0.260E+14, Qx= 20.23, Qz= 19.28, HRT=.060m																							
T	B	Frf	Vrf	Phis	Phib	Iac	Pow	Phi1	Phi2	Bf	Pf	dp/p	Qs	srkt	srkc	srkb	jz/n	zinc	zinc	zinc	zinc		
(GeV)	(T)	(MHz)	(kV)	(deg)	(deg)	(Amp)	(MW)	(deg)	(deg)	(deg)	(deg)	(%)	(%)	(deg)	(deg)	(deg)	(deg)	(deg)	(deg)	(deg)	(deg)		
2.00	0.3340244	2938.	0.0	9.3	1.5	0.00	-97.2	97.2	341	718	140	1575	0.910	869	0.748	116.	0.115	172	-0.02	0.04	0.005	0.022	
2.24	0.3640569	3646.	7.4	9.3	1.5	0.47	-74.3	96.6	303	719	145	1546	0.913	895	0.781	99.	0.103	160	-0.02	0.04	0.004	0.019	
2.93	0.4411.98	3381.	15.4	18.3	1.7	0.91	-53.9	95.0	267	717	133	1561	0.908	912	0.793	64.	0.076	120	-0.01	0.03	0.002	0.012	
4.02	0.57417.01	2995.	24.4	27.8	1.8	1.26	-33.5	95.4	231	715	119	1647	0.902	926	0.797	36.	0.052	0.83	-0.01	0.02	0.001	0.006	
5.41	0.74420.01	2686.	32.7	36.3	1.9	1.50	-15.9	94.7	198	715	107	1933	0.902	935	0.802	19.	0.036	0.58	-0.01	0.01	0.001	0.003	
6.96	0.92421.67	2396.	39.6	43.1	1.9	1.58	-2.2	94.1	173	719	099	1949	0.911	941	0.813	9.	0.026	0.43	-0.01	0.01	0.000	0.002	
8.52	1.10422.58	2062.	44.2	48.1	2.0	1.50	7.9	93.7	154	728	092	1965	0.936	944	0.836	4.	0.019	0.33	-0.01	0.01	0.000	0.001	
9.92	1.27423.09	1654.	48.3	51.5	2.0	1.28	14.6	93.4	141	743	087	1915	0.981	946	0.876	1.	0.016	0.27	-0.01	0.01	0.000	0.001	
11.04	1.40423.37	1173.	50.0	53.0	2.0	0.93	17.7	93.3	136	765	082	1983	1.049	947	0.937	1.	0.014	0.23	0.00	0.01	0.000	0.001	
11.75	1.49423.51	633.	48.2	51.3	2.0	0.49	14.5	93.2	141	787	075	1959	1.137	946	1.017	2.	0.012	0.20	0.00	0.01	0.000	0.001	
12.00	1.52423.56	5.	0.0	0.0	1.6	0.00	-97.2	97.2	341	899	030	0009	1.806	869	1.484	-2.	0.008	0.10	0.00	0.01	0.000	0.001	
zinc,exz,xiz,xiz=.15 .41 .13 .58												zinc,exz,xiz,xiz=.14 .41 .17 .57											
-dQ												-dQ											
12.00	0.42423.56	116.	0.0	0.0	1.6	0.00	-97.2	97.2	341	708	030	0056	0.884	869	0.727	-5.	-0.08	0.25	-0.17	0.16	0.002	0.005	
13.17	0.46423.73	3188.	44.6	47.9	2.0	2.33	7.6	93.7	155	727	061	0256	0.935	944	0.835	-6.	-0.04	0.29	-0.16	0.15	0.003	0.008	
16.58	0.57424.07	5540.	50.3	53.3	2.0	4.43	18.3	93.3	135	723	057	0296	0.924	947	0.825	-7.	-0.04	0.22	-0.13	0.12	0.002	0.005	
21.88	0.75424.32	7289.	53.6	56.4	2.0	6.10	24.5	92.9	123	715	048	0290	0.906	949	0.810	-8.	-0.04	0.16	-0.10	0.09	0.001	0.002	
28.57	0.96424.46	8327.	55.9	58.6	2.0	7.17	28.7	92.9	115	710	039	0263	0.886	949	0.791	-9.	-0.04	0.11	-0.08	0.07	0.000	0.001	
35.99	1.21424.54	8624.	57.2	59.8	2.0	7.54	31.1	92.8	111	702	033	0232	0.865	949	0.773	-9.	-0.03	0.09	-0.06	0.05	0.000	0.001	
43.41	1.45424.58	8166.	57.6	60.2	2.0	7.17	31.9	92.7	109	691	028	0201	0.844	950	0.755	-10.	-0.03	0.07	-0.05	0.04	0.000	0.000	
50.10	1.57424.60	7003.	56.9	59.4	2.0	6.10	30.8	92.2	110	674	024	0171	0.824	951	0.740	-10.	-0.03	0.06	-0.04	0.04	0.000	0.000	
55.41	1.6424.62	5175.	55.4	58.1	2.0	4.43	27.8	92.9	117	673	020	0139	0.802	949	0.717	-10.	-0.03	0.05	-0.04	0.04	0.000	0.000	
58.82	1.75424.62	2583.	51.0	54.0	2.0	2.33	19.6	93.2	132	860	017	0103	0.775	947	0.693	-10.	-0.03	0.04	-0.04	0.03	0.000	0.000	
60.00	1.99424.62	70.	0.0	0.0	1.6	0.00	-97.2	97.2	341	562	006	0015	0.600	869	0.493	-10.	-0.03	0.04	-0.04	0.03	0.000	0.000	

TABLE III

Initial Parameters of an Advanced Hadron Facility Compared with Earlier Designs

	LAMPF II		High Energy Complex		PSR	LANSC E II
	Booster	Main Ring	Booster	Main Ring	Storage Ring	
Kinetic Energy (GeV)	0.797 - 6.0	6.0 - 45.0	2.0 - 12.0	12.0 - 60.0	0.797	2.0
Rep. Rate (Hz)	60	3.33 (6.67)	6.0 (12.0)	6.0 (12.0)	12	12
Protons/Pulse	1.5×10^{13}	6.0×10^{13}	2.6×10^{13}	2.6×10^{13}	5×10^{13}	2.6×10^{14}
Average Current (μ A)	144	32 (64)	25 (50)	25 (50)	100	500
Circumference (m)	320.83	1333.23	1200	1200	-	1200
Number Superperiods	6	2	2	2	10	2
Horizontal Tune	5.22	7.45	20.22	7.47	2.25	20.2
Vertical Tune	4.28	6.45	21.28	8.45	3.25	19.3
Transition Gamma	14.53	6.4	20+	6.8	3	4.0
Magnet Waveform	Sinusoidal	Linear	Quasi Linear	Quasi Linear	DC	DC
Rise time (ms)	11.75	50	41.6	41.6	-	-
Fall time (ms)	3.92	50	41.6	41.6	-	-
Injected emittance						
ϵ_x (π mm-mrad)	15 (60)	3.1 (12.4)	3.4 (12.8)	0.73 (2.93)	30	50
ϵ_y (π mm-mrad)	15 (60)	3.1 (12.4)	3.4 (12.8)	0.73 (2.93)	30	50
ϵ_z (eV-sec)	0.078	0.10	0.0075	0.0075	-	0.018
Maximum Laslett tune shift						
$d\nu_x$	-0.066	-0.010	-0.08	+0.009	-	-0.09
$d\nu_y$	-0.130	-0.035	-0.17	-0.026	0.25	-0.14
bunching factor	0.33	0.15	0.34	0.15	-	0.34
rf frequency (MHz)	50.31 - 59.26	59.26 - 59.80	402.5 - 423.6	423.6 - 424.6	-	402.5
Harmonic Number	66	266	1700	1700	1	1700
Max Voltage/turn (MV)	1.6	6.0	3.6	8.8	-	7.3
Circulating Current (Amps)	2.2	2.2	1.0	1.0	27	7.5
Max Power to Beam (MW)	1.7	7.9	1.6	7.5	-	0
Max ν_s (synch. tune)	0.056	0.015	16	0.03	0.0003	0.15

The 2-GeV linac energy is arbitrarily chosen because the velocity of a proton of this energy is 0.95 c. This makes tuning of the booster frequency (5%) possible with reasonable klystrons. In addition, the high injection energy reduces the required magnet apertures in all three rings by a large factor.

There are a number of issues requiring further study. These include:

1. design of neutron source target cell;
2. effects of high synchrotron frequency;
3. design of lattices; and
4. cost and feasibility of 400-MHz rf.

Until more design work is done, we cannot get a reliable cost estimate. Nevertheless, I suggest that the following estimates for material plus installation are a reasonable guess:

TABLE IV

Comparison of LAMPF II and AHF Cost (1985 Dollars)
(Material + Installation)

	<u>LAMPF II</u>	<u>AHF</u>	<u>Difference</u>
Low-E Conv. Facilities	\$ 31.5	\$ 28.8	\$ -2.7
Linac	-	50.0	+50.0
Booster	42.4	38.3	-4.1
Compressor Ring	-	25.0	+25.0
Pulsed Muon Facilities	-	18.0	+18.0
Area N	10.3	40.0	29.7
High-E Conv. Facilities	27.6	27.6	0.0
Main Ring	77.8	49.7	-28.1
Area A	64.0	61.1	-2.9
	<hr/>	<hr/>	<hr/>
Total	\$253.6	\$338.5	\$ 84.9

The costs shown in Table IV are hardware plus installation only. These must be multiplied by a factor of 2.3 to arrive at "out-year" costs including ED&I, project management, contingency, and inflation.

CONCLUSIONS

A combined kaon factory/cold-neutron source makes economic sense, since there is a savings on the order of 20% in items that can be shared. An rf of 400-MHz seems to be feasible, but further study is required to decide whether the improvements are worth the risk of lesser stability.

The AHF cost estimates shown in this report are guesses not based on detailed designs. Significant changes may be expected as we proceed to detailed design.

A smaller circumference compressor ring might be more advantageous, even if the cost of a new tunnel is included.

Note of Caution

This proposal is but one of several options that should be considered before choosing a design strategy.